Building artificial neural networks to predict direction and magnitude of wind, current and wave for sailing vessels

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Abstract

Current, wind, wave direction and magnitude are important factors affecting the course of ships. These factors may act positively or negatively depending on the course of a vessel. In both cases, optimisation of the route according to these conditions will improve the factors such as labour, fuel and time. In order to estimate the wind, wave, current direction and magnitude for the region to be navigated, it is necessary to develop a system that can make predictions by using historical information. Our study uses historical information from the E1M3A float—a part of the POSEIDON system. With this information being used, artificial neural networks were trained and three separate artificial neural networks were created, which can predict wind direction and speed, direction and speed of sea current, wave direction and height. For different regions, it is necessary to use artificial neural networks trained using the historical information of those regions. This study is an example of prospective studies.

Keywords: Current, neural network, prediction, sailing vessels, sea, wave, wind.

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1. Introduction

The wave direction, wave height, current direction and speed on the area to be navigated play an important role in the route choice of the ships. In the literature, there have been studies aimed to calculate how weather and sea conditions affect the speed and course of the ship, and how the velocity of the ship can be affected in response to changing factors [5], [10].

Estimation of wind intensity is a subject that is often studied in areas such as wind power generation and agriculture [3], [8]. Various methods are used to estimate wind speed. When the studies are examined, it has been seen that linear prediction methods [1], methods using multiple architectures [2], methods based on probability [9], methods based on Kalman Filter [8] and methods based on artificial neural networks [3] [8] have been used. In the literature survey, it was seen that there have been studies on the estimation of wave height [11] used and is to predict the wave height in a certain area of Turkey [6] used the neural network, fuzzy and neuro-fuzzy methods to predict wave height for Lake Ontario. Artificial neural networks were used in our work. Using artificial neural networks, a system has been developed that predicts what the wind, current and wave conditions may be in the sea depending on the changing weather conditions. The information used to train artificial neural networks was derived from the E1M3A float, a float of the POSEIDON system. The information can be accessed on the IFREMER website [4]. The E1M3A flood is a flood in the 35.74474° north, 25.12606° east location, instantaneously sending to the POSEIDON system by measuring air pressure, air temperature, wind speed, wind direction, wave height, wave direction, flow direction and speed [7].

Figure 1A. Poseidon system floats, Figure 1B. Online information gathered from E1M3A

Figure 1A shows the float locations obtained from the POSEIDON system and Figure 1B shows the online data taken from E1M3A float.

2. Material and Methods

2.1. Information gathered from IFREMER system

The data used in the study were obtained from the IFREMER system in the form of nc extension files [9]. Files are read on this format and saved in excel files. This is the way to use nc extension files as it will affect the speed of reading and using the program at runtime. Just before the system works, the information is read from the excel file, converted into a matrix and transferred to the system. Figure 2 shows the information obtained. The information in the file includes air temperature, flow direction, flow velocity, wave direction, atmospheric pressure, wave height, wind speed, date and wind direction.
In addition to these, the wind category columns have been added by us so that we can express the lunar slope, wind or current directions as words to understand which month the data are obtained.

The proposed network is trained separately so that it can make three different estimates. Estimates were obtained in three different ways: direction and speed of current, wind direction and speed and wave direction and elevation. The input, output, number of neurons, latency, validation, testing and training parameters of the generated networks are as shown in Table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>System to predict wind direction and speed</th>
<th>System to predict current direction and speed</th>
<th>System to predict wave direction and height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Temperature, pressure, month</td>
<td>Temperature, Pressure, month, wind speed, wind direction</td>
<td>Temperature, pressure, month, wind speed, wind direction</td>
</tr>
<tr>
<td>Neuron</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Number</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Outputs</td>
<td>Wind direction, wind speed</td>
<td>Current direction, current speed</td>
<td>Wave direction, wave height</td>
</tr>
<tr>
<td>Validation</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
</tr>
</tbody>
</table>
3. Results

3.1. Results of the system that predicts the current speed and direction

In order to examine the accuracy of the system estimating the current speed and direction, the data for January 2007 was taken and applied as an input to the system. Since the measurements are 3 hours apart, 8 measurements for 1 day and 240 measurements for 1 month are taken and the values that should be estimated with the system are measured and presented in Figure 4.

![Figure 4. Results of the system that predicts wave direction and height](image)

It was observed that the system was quite successful in estimating the speed of the current. When the direction of the current is predicted, it is observed that the error rate increases in the direction changes, but the recovery period is short. As seen from the figure, there was a sudden change in the direction after the 170th measurement, the system made erroneous predictions, but this process has survived the 190–200 measurements. The 200th measured income was again a change of direction, the system gave incorrect values but dropped the error to 240th measure. It has been seen that the system generally succeeds when there is no sudden change of direction.

3.2. Results of the system that predicts the wind speed and direction

As seen in Figure 5, it was observed that the system for predicting wind speed and direction was successful in predicting wind speed and direction. Errors in the prediction of the direction of flow have been observed to decrease in this system. The wind direction and speed were much related to temperature and pressure depending on the seasonal conditions, so the error did not occur at high rates.
3.3. Results of the system that predicts the wave speed and direction

When the results of the system estimating the wave direction and height are examined in Figure 6, it is observed that the system is successful in estimating the wave height. Although some errors were observed without guessing the wave direction, the system predicted the output as values above 360 in some measurements where the actual output value is close to 0, as can be seen at points called 1,2,3,4 and 5 on Figure 6, reflected as if there were high erroneous values.

However, the estimates at the measurement points in Figure 6 and the required output values are as in Table 2.
Table 2. Examination of the error values of the system that predicts wave direction and height

<table>
<thead>
<tr>
<th>Observation no.</th>
<th>Prediction</th>
<th>Real observation</th>
<th>Actual error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>414°</td>
<td>5°</td>
<td>49°</td>
</tr>
<tr>
<td>2</td>
<td>353°</td>
<td>27°</td>
<td>34°</td>
</tr>
<tr>
<td>3</td>
<td>377°</td>
<td>9°</td>
<td>8°</td>
</tr>
<tr>
<td>4</td>
<td>368°</td>
<td>8°</td>
<td>0°</td>
</tr>
<tr>
<td>5</td>
<td>380°</td>
<td>1°</td>
<td>19°</td>
</tr>
</tbody>
</table>

4. Discussion

When the performance of the three systems is evaluated in general, it is seen that the system that predicts the wind direction and speed and the wave direction and height estimation systems are successful. It is explained why the values that seem to be errors in direction estimation are obtained. In the current direction and speed prediction system, it is thought that the cause of the high error in some areas of the prediction depends on the sudden change in the direction of the current. The sudden change of direction of current is thought to be caused by the transition of the regional and small currents on the sea surface when a decline in the speed of the wind that directs the current. The information in Figure 4 confirms this. When Figure 4 is examined, it is seen that the wind speed decreases after the 170th measurement and accordingly the sudden changes in the direction of the current occurs.

The general performance of the prediction systems are calculated by means of mean squared error (mse), and regression coefficient (R) using equation 1 and 2.

\[
\text{mse} = \frac{\sum_{t=1}^{n} (e_t - o_t)^2}{n}
\]

\[
R = \frac{\sum_{t=1}^{n} (e_t - \bar{e}_t)(o_t - \bar{o}_t)}{\sqrt{\sum_{t=1}^{n} (e_t - \bar{e}_t)^2} \sqrt{\sum_{t=1}^{n} (o_t - \bar{o}_t)^2}}
\]

The mean squared error and regression values of the proposed systems can be seen in Table 3.

Table 3. Accuracy of proposed networks

<table>
<thead>
<tr>
<th>System</th>
<th>Mean squared error</th>
<th>Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current direction and speed prediction</td>
<td>7.82</td>
<td>0.91853</td>
</tr>
<tr>
<td>Wind direction and speed prediction</td>
<td>7.02</td>
<td>0.94828</td>
</tr>
<tr>
<td>Wave direction and height prediction</td>
<td>7.82</td>
<td>0.91853</td>
</tr>
</tbody>
</table>

5. Conclusions

Three forecasting systems for estimating weather and marine conditions for ships were carried out using artificial neural networks.

The success achieved in artificial neural network studies related to wind speed and wave height was also obtained in this study. Although the direction estimation part of our study seems to have a high error because it yields degrees, when the result obtained from the artificial neural network exceeds 360 degrees, 360 is actually subtracted from the value. Detailed information related to this situation is given in the findings section.
In general, in this study, artificial neural networks that learn and predict by using historical information were constructed to predict important parameters in terms of ship navigation and the results obtained by the system were satisfactory.

References